STEREO Guidance & Control

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STEREO G&C

- Requirements
- Baseline System
- Software
- Some Analysis

G&C Requirements - Drivers

- Spacecraft pointing - (3 σ)

	Roll	Pitch/Yaw
– Knowledge:	± 20 arcsec	± 0.1 arcsec
– Control:	± 0.1 degree	± 20 arcsec
– Jitter:	30 arcsec RMS	1.5 arcsec (0.1 to TBD Hz)

  (with SCIP error signal, which is ± 0.1 arcsec)

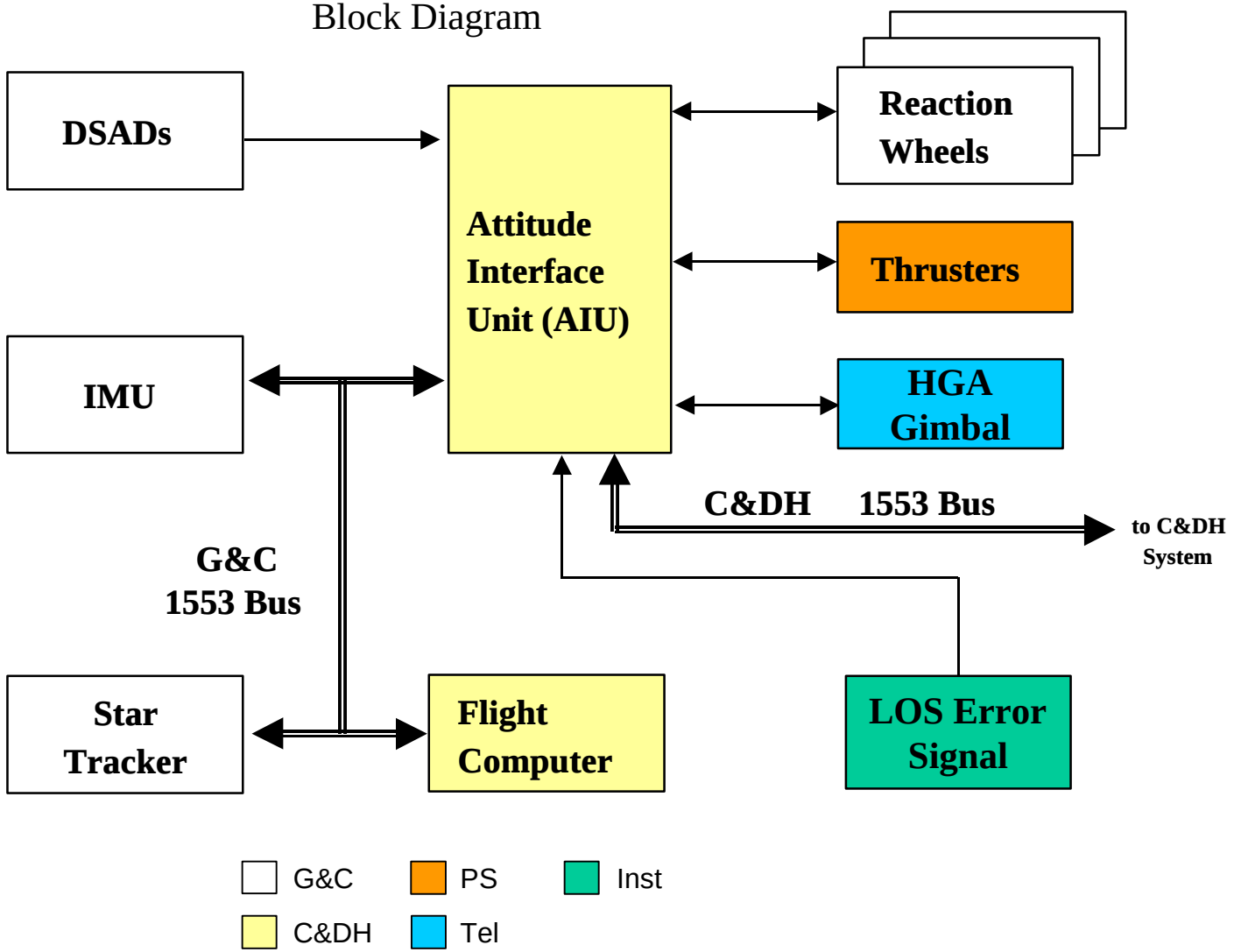
- Jitter is challenge
- Need high control bandwidth =>
  - High wheel torque
  - Fast sampling rate
  - Minimize disturbances
  - Modern control techniques

Interesting G&C Requirements

- Point LOS within 5 arcmin of sun for SCIP acquisition
  - Requires good coalignment
- Nominal HGA pointing to 0.1°; Maintain HGA pointing during thrusting; Complete autonomous thruster firings within 300 seconds
  - Sets gimbal step frequency
  - Need small impulse bit & small Δt
  - In-flight HGA alignment cal ?
- Momentum storage capacity > 4 days in operational mode
  - Sizes wheel momentum
- Return from any attitude in < 12 minutes
  - Thruster attitude control ?
  - May size wheel torque
- On-board orbit propagation for pointing HGA at Earth distance > 1e6 km
  - Autonomous navigation ?
- Solar pressure momentum bias within sun-angle limit
  - Solar c.p. trim ?

STEREO Guidance & Control System

Block Diagram



Baseline G&C Equipment

Item	Heritage	Performance
IMU	NEAR	HRG, 0.01 deg/hr$^{1/2}$
Star tracker	TIMED	3 arc sec, 7.5 Mv stars
Reaction Wheels	NEAR	Torque: 0.025 Nm Momentum: 4 Nms
Sun Sensors	NEAR	0.5 deg quantization 0.25 deg accuracy
AIU	TIMED	No
Flight Computer	TIMED	Yes

Inertial Measurement Unit (IMU)

- Supplier: Delco Electronics
- Gyros:
  - Delco 130Y Hemispherical Resonator Gyros (HRG)
  - Rate bias stability < 0.001 deg/hr, over 16 hr
  - ARW < 0.01 deg/$hr^{1/2}$
- Redundancy:
  - NEAR: redundant CPU, power; 4 gyros
  - Cassini: single-string
- Projected P_S (system function) = 0.9996 for mission life
  - (4 gyro IMU)

Star Tracker

- Supplier: Lockheed Martin
- Accuracy :
  - 3 arcsec P/Y; 32 arcsec R (1σ)
  - 7.5 Mv stars
  - 8.8° square FOV
- Quaternion output
  - Autonomous star ID within ~2 sec
  - 5 Hz update, 1553 interface
- Flown on DS1, P59; to fly on TIMED, EO1, MAP, IMAGE, ...

Reaction Wheel Assembly (RWA)

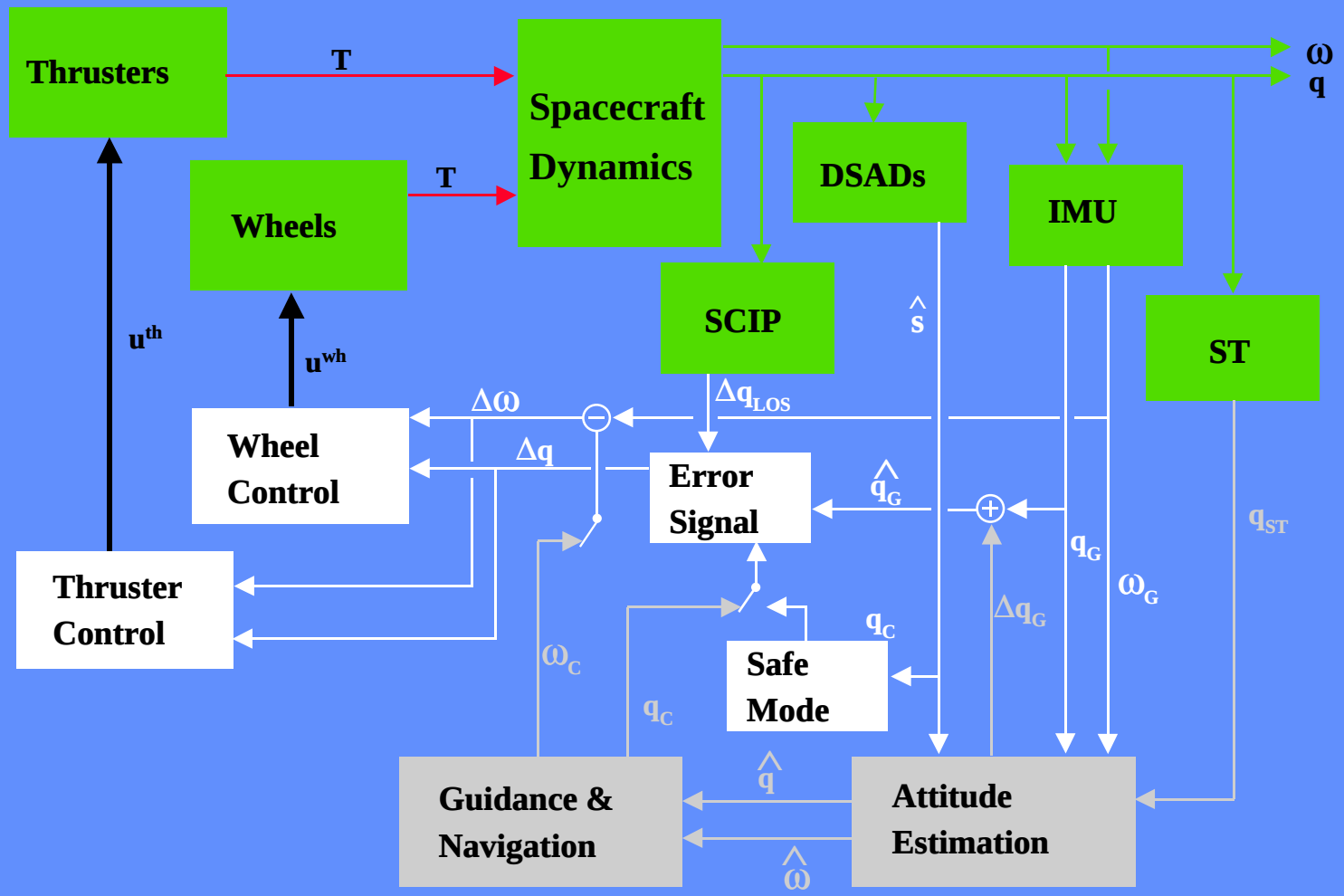
- Supplier: Ithaco, Inc. (Type A)
- Characteristics:
  - Brushless DC motor
  - Bipolar tachometer
  - Separate electronics, stacked to save weight & space
- Performance:
  - Angular Momentum: 4 Nms (@ 5100 RPM)
  - Torque: 0.025 Nm
  - Unbalance:
    - static: < 1.5 gm cm
    - dynamic: < 40 gm cm^2
  - Torque noise PSD: 1×10^{-11} $(Nm)^2/Hz$, 0.1 to 1 Hz
  - Continuous operating life: > 4 years

Sun Sensors (DSAD)

- Supplier: Adcole
- Digital Solar Attitude Detector (DSAD) system
  - 5 detector heads, each measures 2-axis sun vector in ±64° FOV
- Accuracy:
  - 0.5 deg quantization
  - 0.25 deg bit transition-angle accuracy
- Flight proven, many times

Guidance & Control

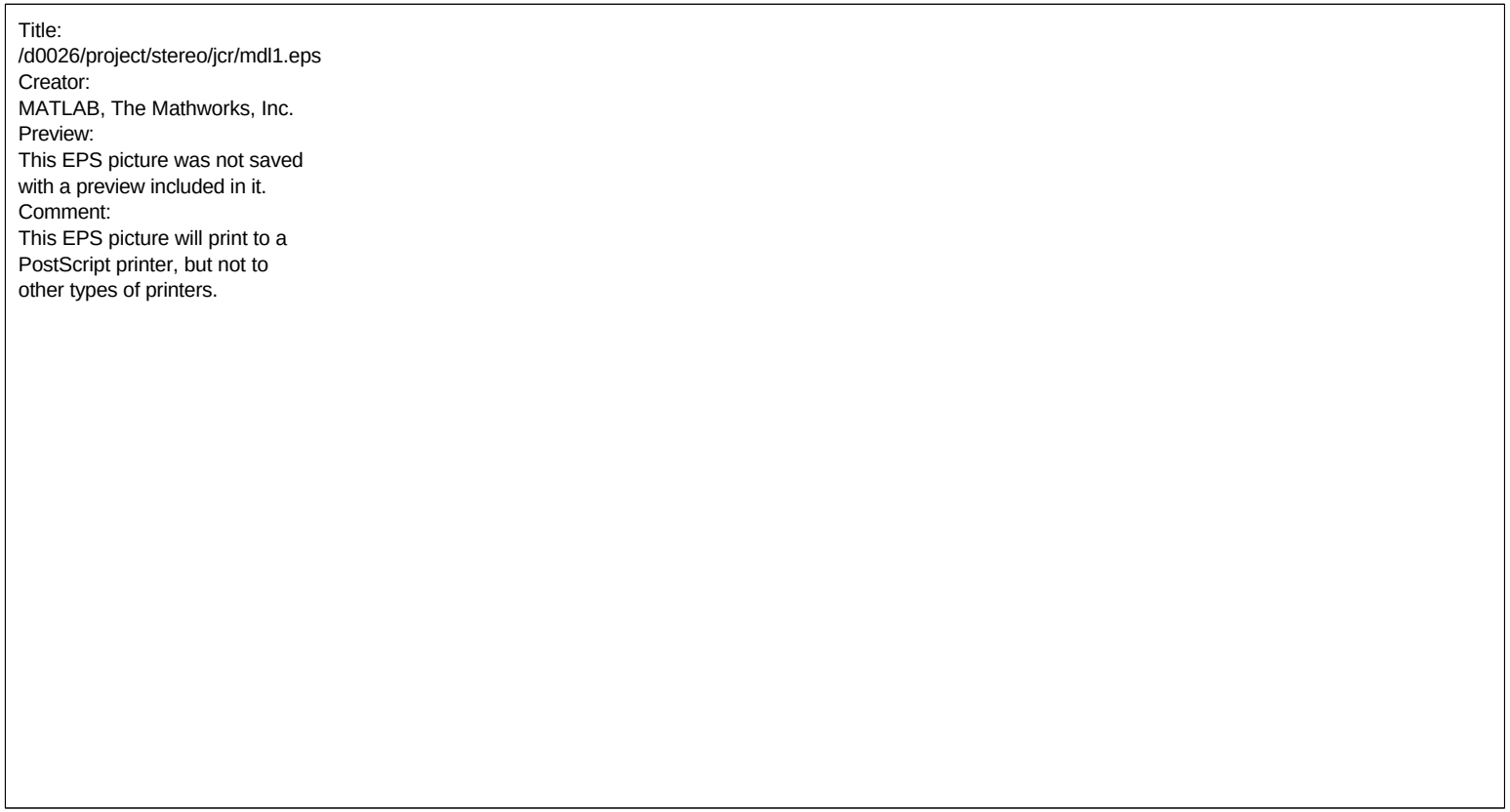
Functional Block Diagram



G&C Software

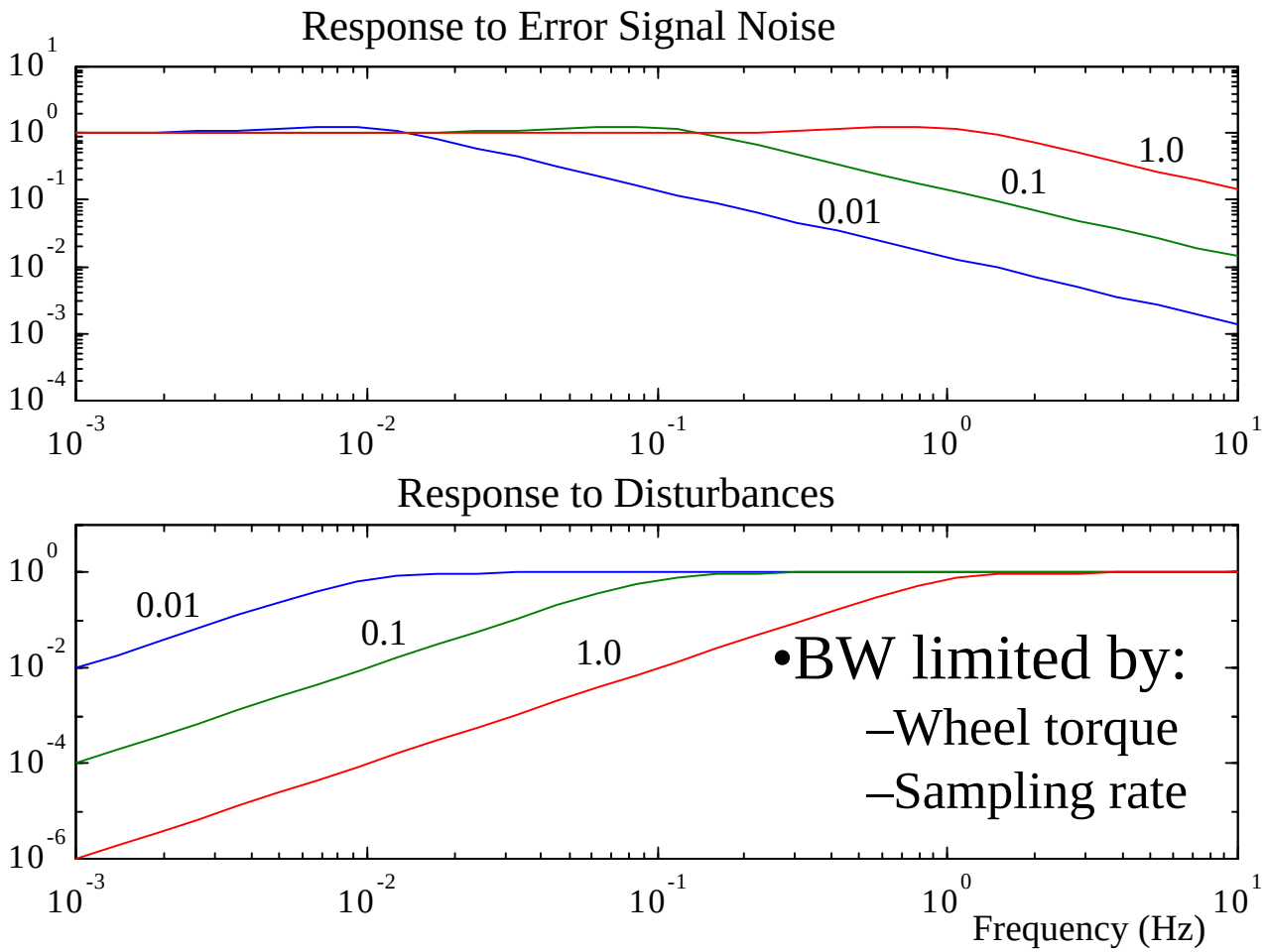
- G&C software will be developed in Simulink
  - Graphical tool for developing system models
  - Runs in Matlab
  - Used on TIMED
- Real-Time Workshop (RTW) used to automatically generate code:
  - Testbed simulator
  - FC
  - AIU?
- System-level modules (e.g. Cmd, TLM, device handlers) may need to be hand-coded

Simulink Model
Top Level

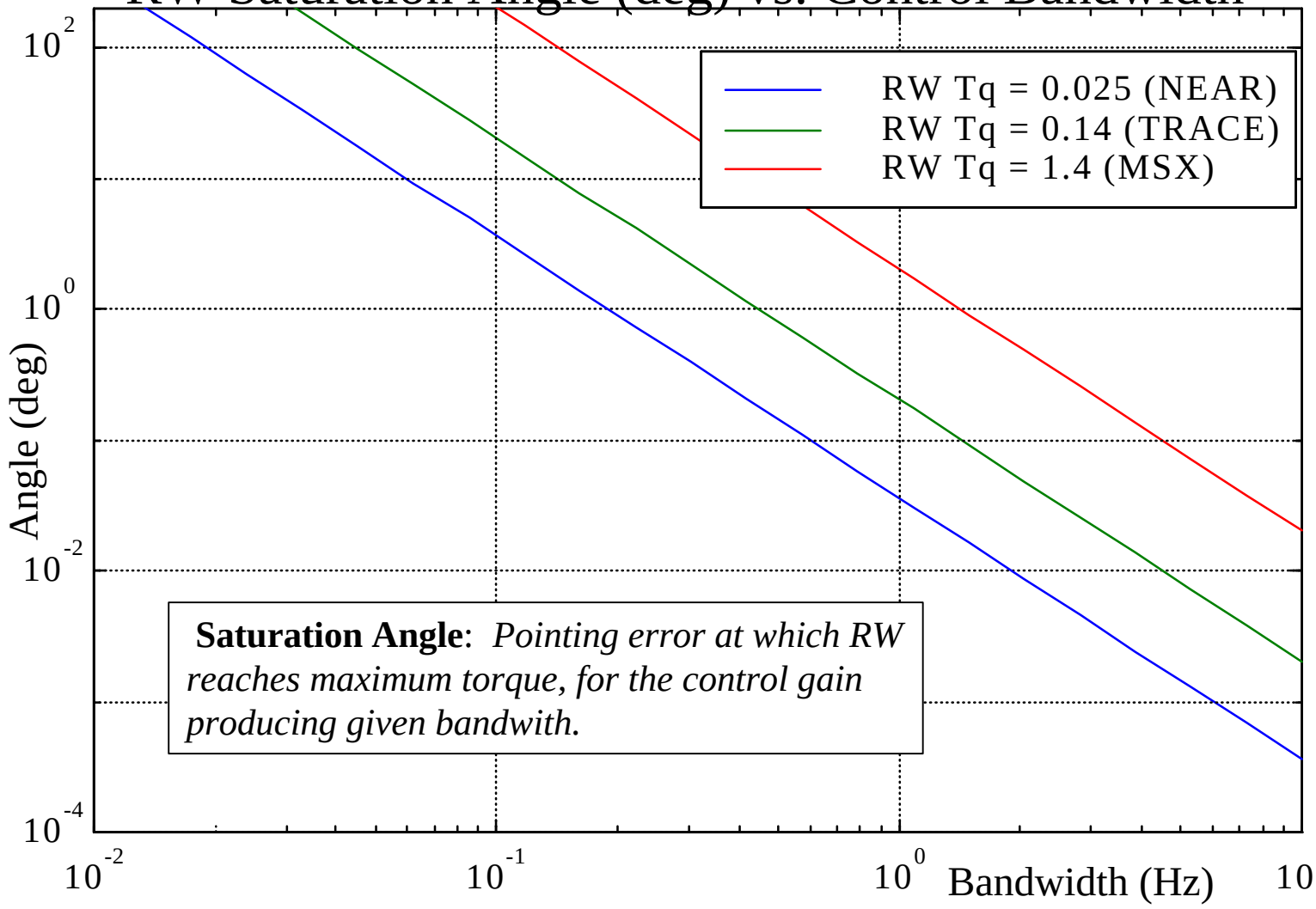


Simulink Model
Dynamics

Control Bandwidth (BW) Effects

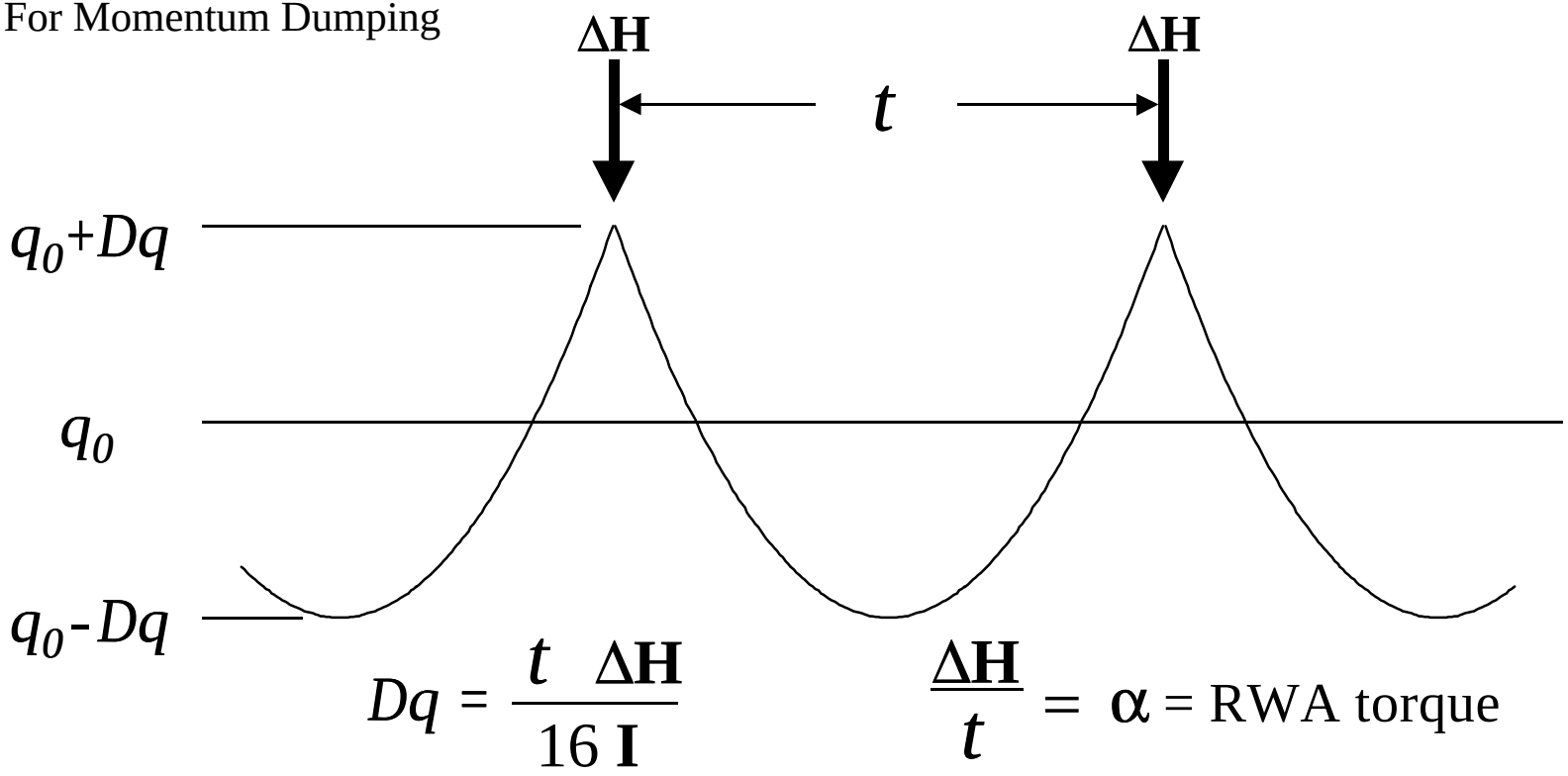


RW Saturation Angle (deg) vs. Control Bandwidth



Limit Cycling

For Momentum Dumping



$$Dq = \frac{t \ \Delta H}{16\ \mathbf{I}} \qquad \frac{\Delta H}{t} = \alpha = \text{RWA torque}$$

- **ΔH is torque impulse bit, I = inertia**
- **For ΔH = 0.02, α = 0.02, I=300 (SI units):**

  Dq **= ~ 4 μrad,** t **= 1**

Momentum Bias Mode

- Possible for safe mode, or if y or z wheel fails -
  - x wheel runs at large fraction of its max speed
  - Other wheel(s) used to damp nutation
  - Precession by thruster firings
- Degraded pointing accuracy -
  - Stability dominated by nutation
  - Accuracy limited by momentum precession
- Fuel for angular momentum precession:
  - About 150 mgm/day for 1 deg/day precession (H=4 Nms, Isp=65 s)
- If x wheel fails -
  - y & z RW control still possible
  - 2-sided thruster limit cycle for x

Redundancy Considerations

- Four Wheels
  - Full capability if any one fails
  - Enable wheel speed control to avoid troublesome frequencies
- Four Gyros
  - Full capability if any one fails
  - Lower noise if all four used
- Fine Sun Sensor
  - In addition to, or in place of, coarse DSADs
  - Enable mission pointing without LOS error signal